



US 20170309023A1

(19) **United States**

(12) **Patent Application Publication**  
**Rothberg**

(10) **Pub. No.: US 2017/0309023 A1**

(43) **Pub. Date: Oct. 26, 2017**

(54) **PORTABLE ELECTRONIC DEVICES WITH  
INTEGRATED IMAGING CAPABILITIES**

**G06T 7/40** (2006.01)

**G06T 19/00** (2011.01)

(71) Applicant: **Butterfly Network, Inc.**, Guilford, CT  
(US)

(52) **U.S. Cl.**

CPC ..... **G06T 7/0012** (2013.01); **G06T 7/40**  
(2013.01); **A61B 8/4411** (2013.01); **A61B**  
**8/4427** (2013.01); **A61B 8/4477** (2013.01);  
**G06T 19/006** (2013.01); **G06T 7/60** (2013.01);  
**G06T 7/90** (2017.01); **G01S 15/899** (2013.01);  
**A61B 8/483** (2013.01); **A61B 8/4494**  
(2013.01); **G06T 2207/10136** (2013.01); **G06T**  
**2207/30008** (2013.01); **G06T 2207/30101**  
(2013.01); **G06T 2219/016** (2013.01)

(72) Inventor: **Noah Zachary Rothberg**, Guilford, CT  
(US)

(73) Assignee: **Butterfly Network, Inc.**

(21) Appl. No.: **15/644,456**

(22) Filed: **Jul. 7, 2017**

#### **Related U.S. Application Data**

(63) Continuation of application No. 15/581,429, filed on  
Apr. 28, 2017, which is a continuation of application  
No. 13/856,252, filed on Apr. 3, 2013, now Pat. No.  
9,667,889.

#### **Publication Classification**

(51) **Int. Cl.**

**G06T 7/00** (2006.01)

**A61B 8/00** (2006.01)

**A61B 8/00** (2006.01)

**A61B 8/00** (2006.01)

**A61B 8/00** (2006.01)

**G06T 7/60** (2006.01)

**G06T 7/90** (2006.01)

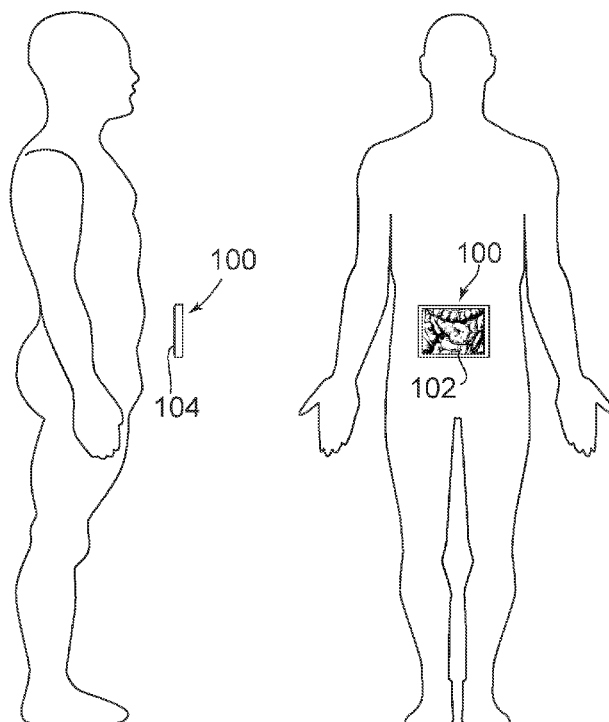
**G01S 15/89** (2006.01)

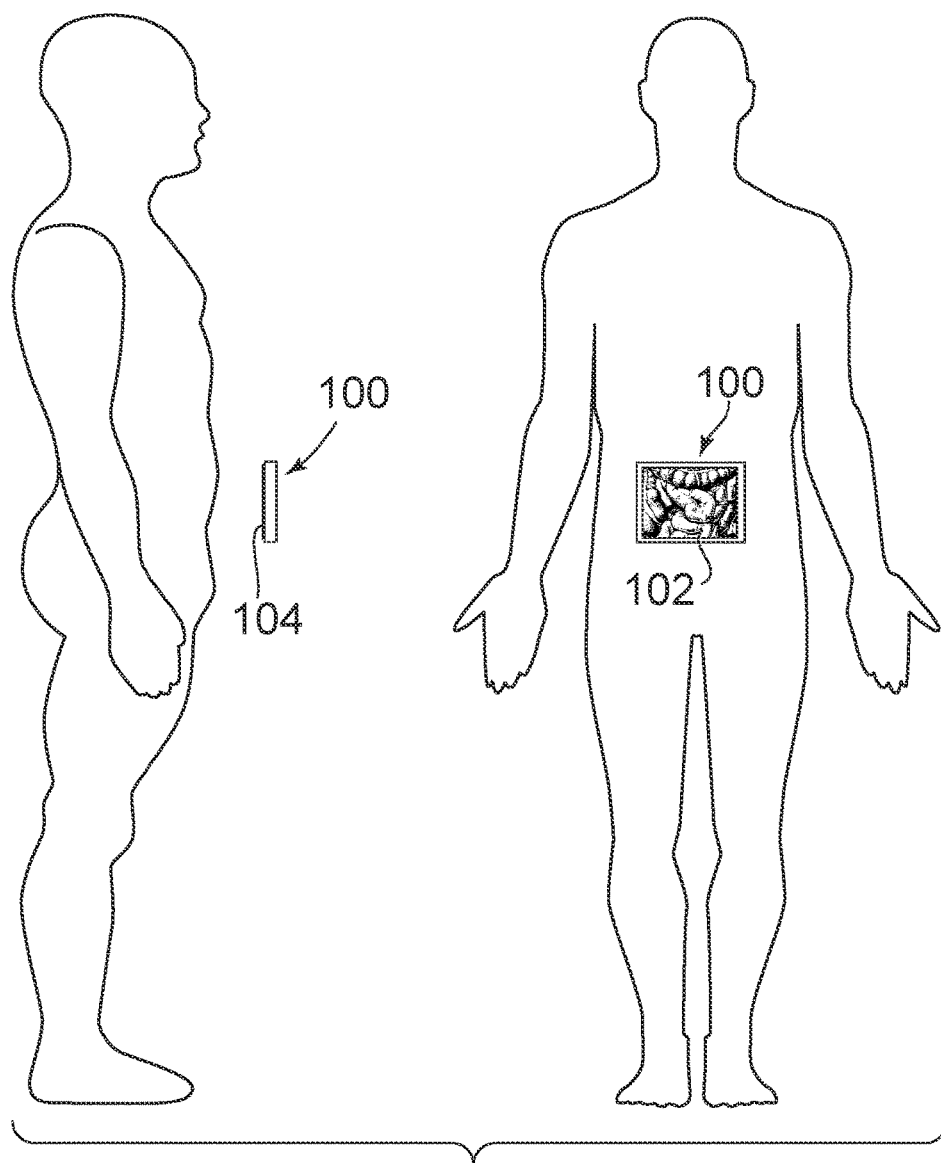
**A61B 8/08** (2006.01)

(57)

#### **ABSTRACT**

A portable electronic device (e.g., smart phone or tablet computer) is provided for generating and displaying images (e.g., 2-dimensional or 3-dimensional images) of an imaging target such as a human body. The portable electronic device may include imaging elements configured to receive radiation signals transmitted through and/or reflected by the imaging target, an imaging interface, and one or more processors. The portable electronic device may display what appears to be a window into the imaging target (e.g., a human body), and/or an exploded view (e.g., 3-dimensional, upwardly projected image) of the target. The generated image may be a real-time continuous image of the internal features of the target (e.g., a human body) that is updated to track movements of the target (e.g., breathing patterns) and the relative position of the portable electronic device as the portable electronic device moves relative to a surface of the target.





**FIG. 1A**

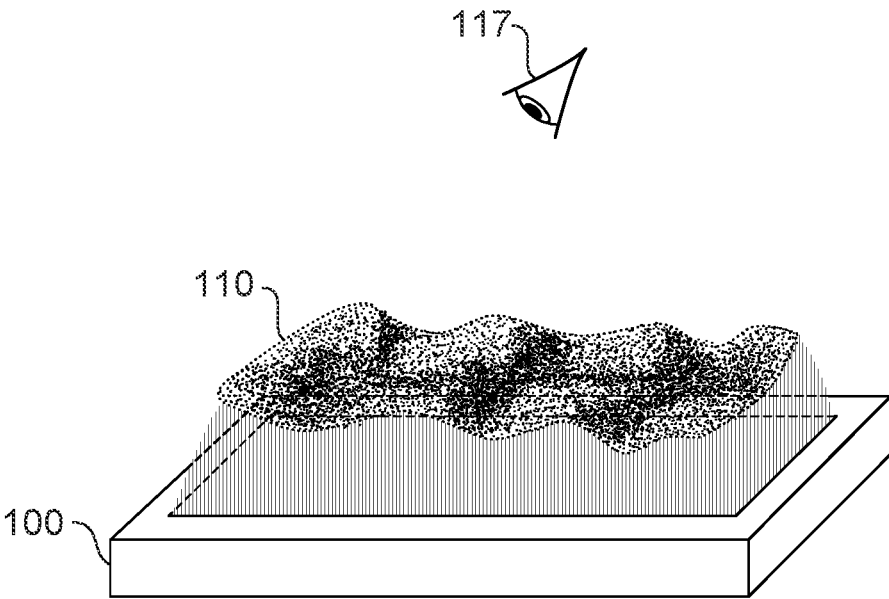


FIG. 1B

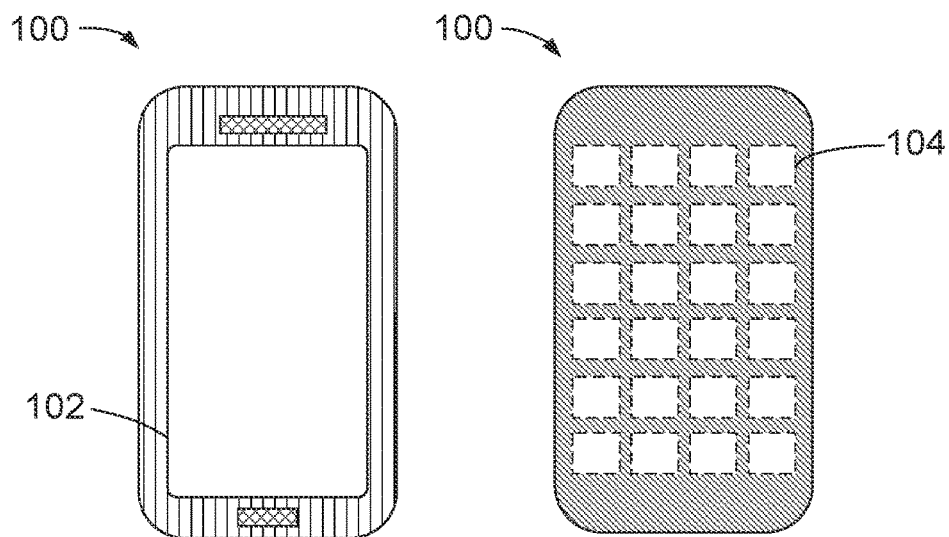


FIG. 2A

FIG. 2B

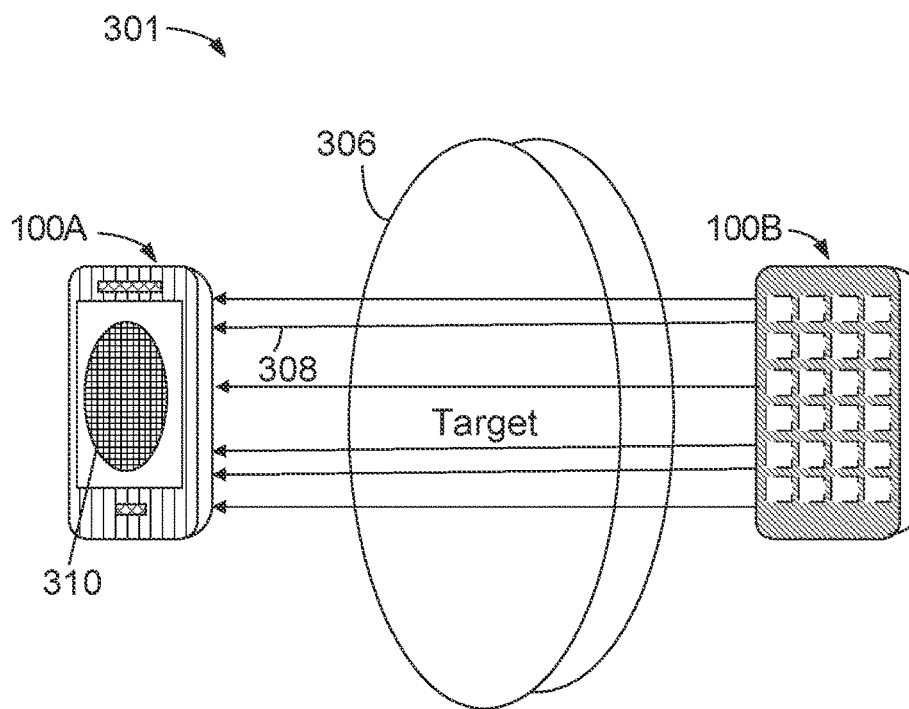


FIG. 3

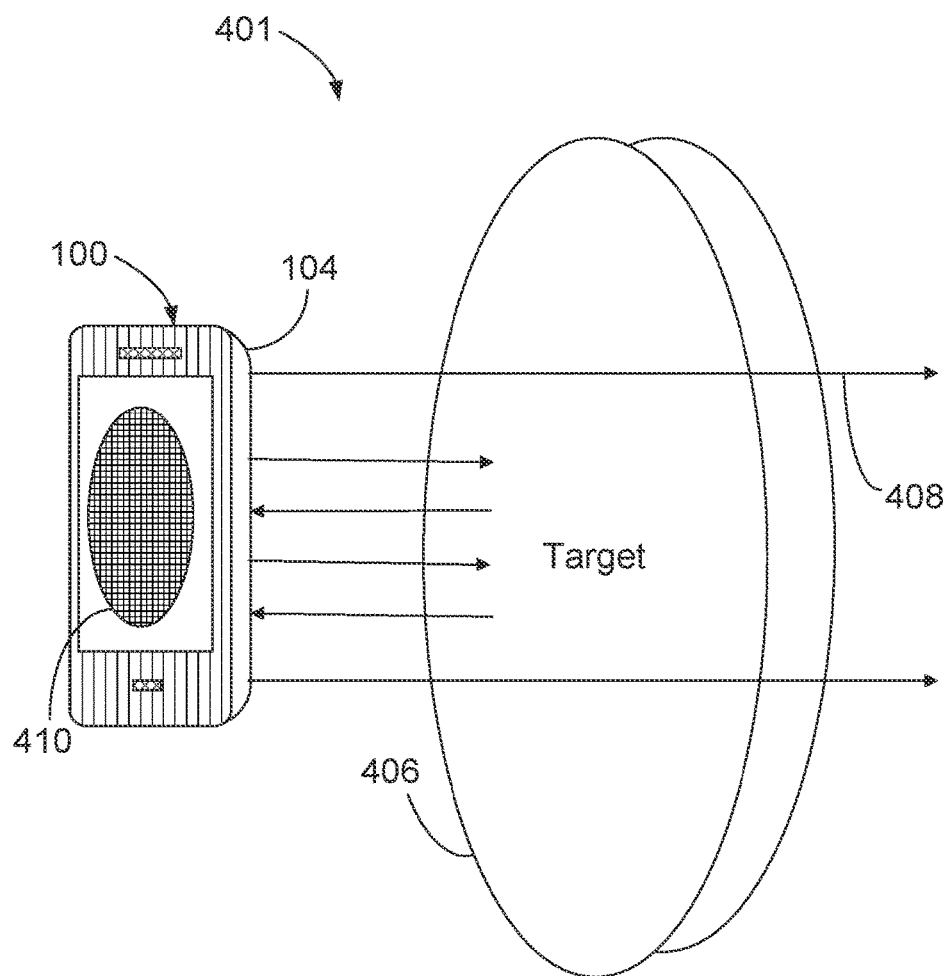


FIG. 4

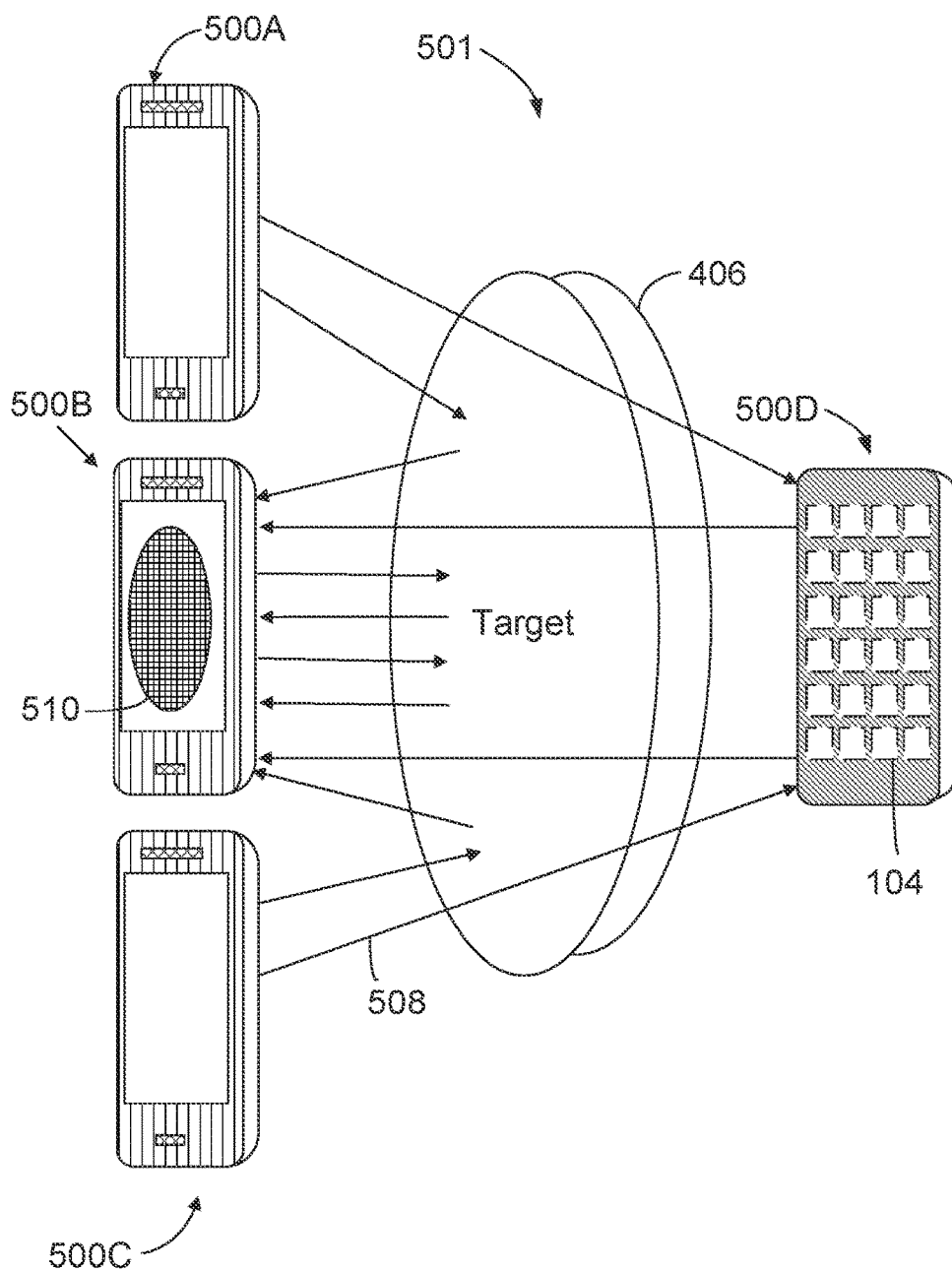
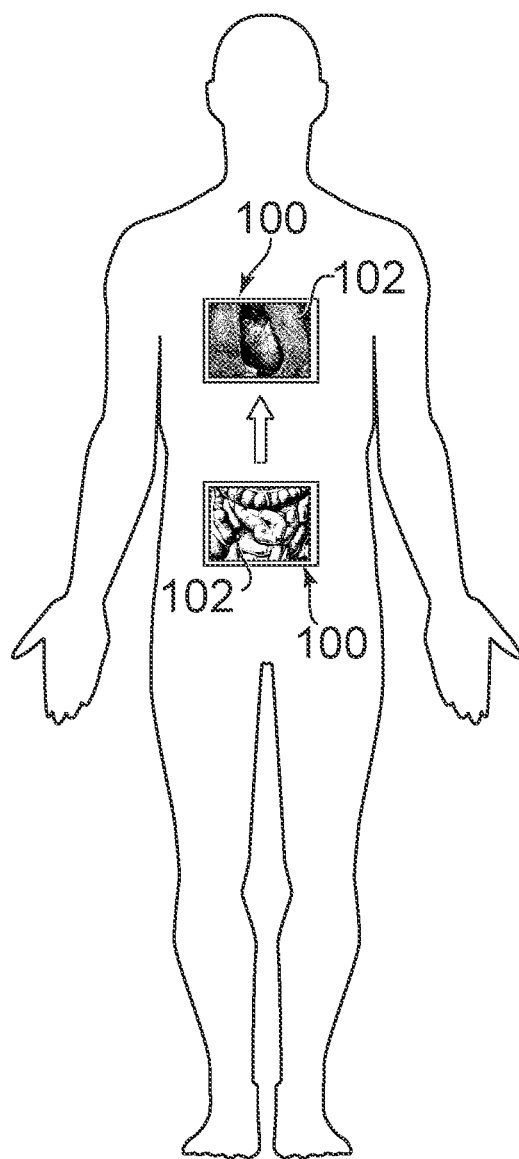


FIG. 5



**FIG. 6A**

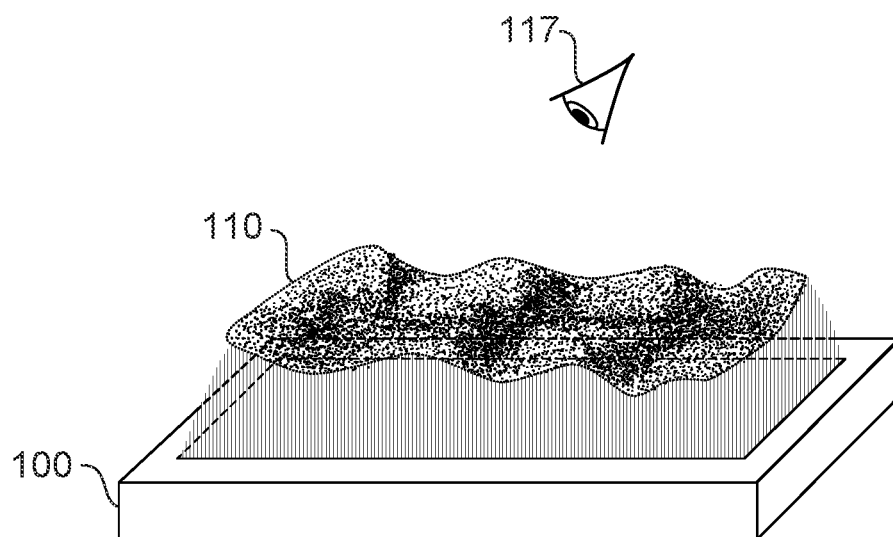


FIG. 6B

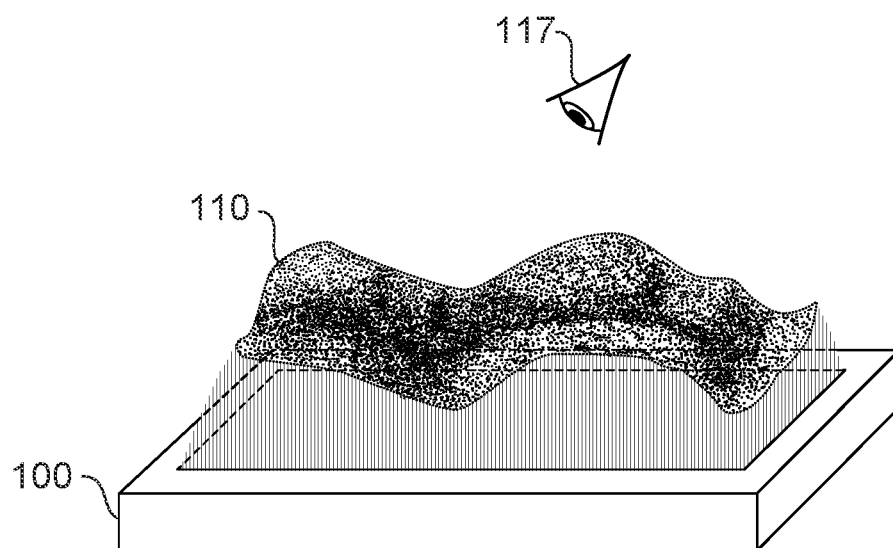


FIG. 6C

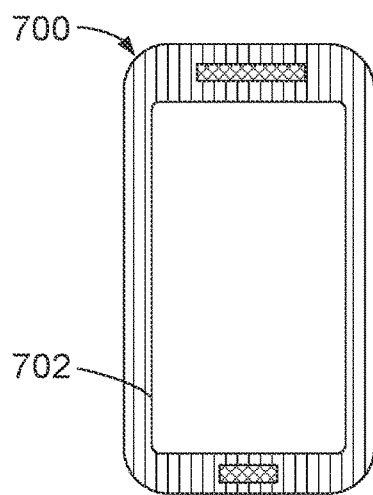


FIG. 7A

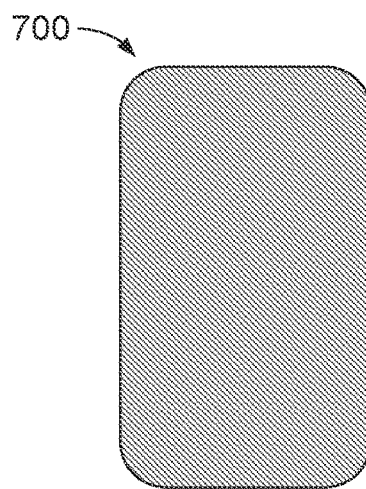


FIG. 7B

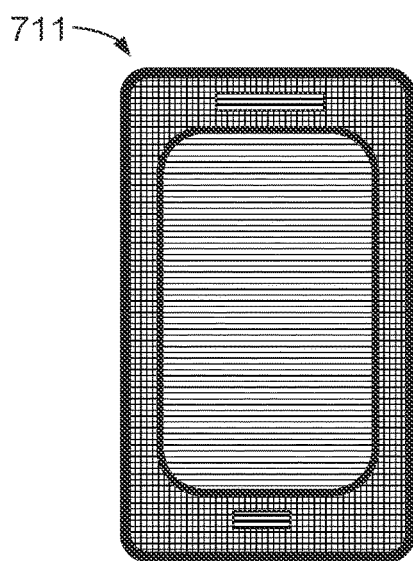


FIG. 7C

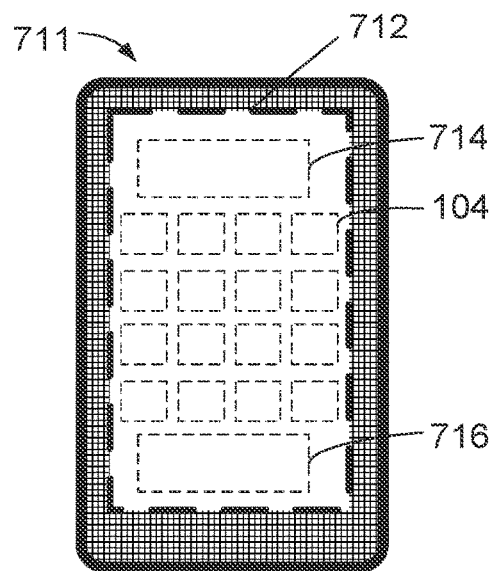


FIG. 7D

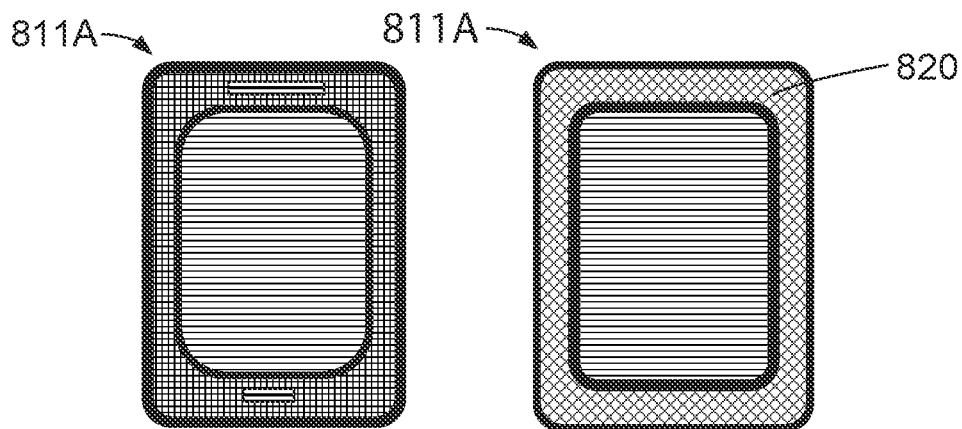


FIG. 8A

FIG. 8B

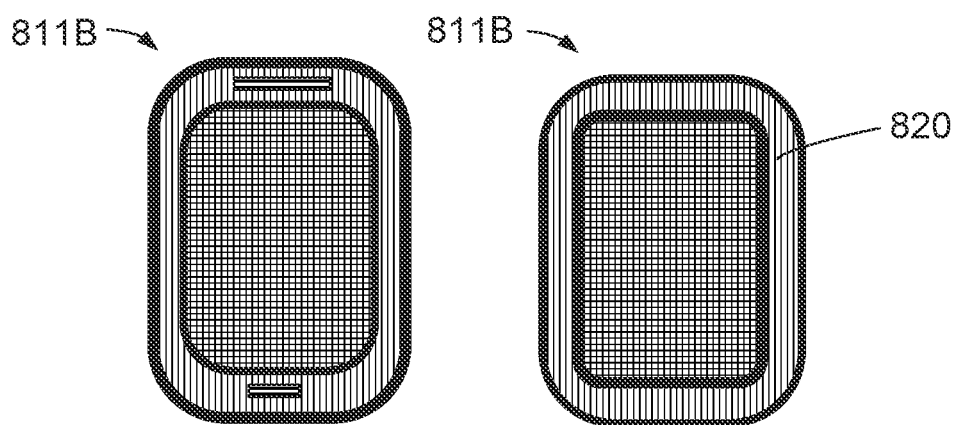


FIG. 8C

FIG. 8D

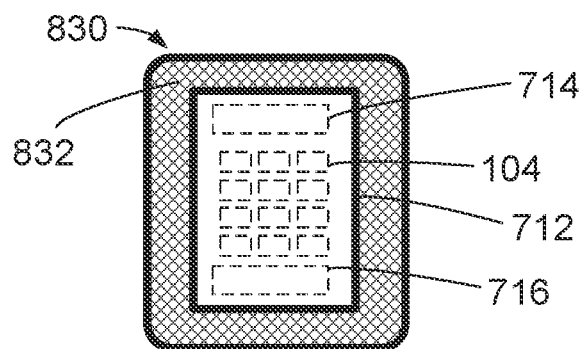


FIG. 8E

## PORTABLE ELECTRONIC DEVICES WITH INTEGRATED IMAGING CAPABILITIES

### FIELD OF THE TECHNOLOGY

[0001] The present disclosure relates generally to imaging devices and methods (e.g., ultrasound imaging devices and methods).

### BACKGROUND

[0002] Imaging technologies are used at various stages of medical care. For example, imaging technologies are used to non-invasively diagnose patients, to monitor the performance of medical (e.g., surgical) procedures, and/or to monitor post-treatment progress or recovery.

[0003] Conventional imaging devices and methods, including magnetic resonance imaging (MRI) technology, are typically configured for and limited to use within a fixed location in a hospital setting. MRI technology is also generally slow, and suffers from other drawbacks including high cost, loud noise, and the use of potentially harmful magnetic fields.

[0004] In view of the foregoing, it would be desirable to provide portable electronic devices and associated methods with integrated imaging capabilities.

### SUMMARY

[0005] Some embodiments of the present disclosure relate to a portable electronic device (e.g., smart phone and/or tablet computer) for generating and displaying an image (e.g., 2-dimensional or 3-dimensional image) of what appears to be a window into an underlying object, such as a human body, when placed in proximity to (e.g., on or close to) the object. The window and corresponding image displayed on a display screen of the portable electronic device change as the portable electronic device is moved over various portions of the body (e.g., abdomen, thorax, etc.). The image displayed by the portable electronic device may identify, for example, organs, arteries, veins, tissues, bone, and/or other bodily contents or parts. In various embodiments, the image may be presented in 3 dimensions such as it appears to the viewer as if the viewer is looking into the body, or as if the body parts have been projected up (e.g., exploded view) from the body.

[0006] The present disclosure provides numerous embodiments of systems, apparatus, computer readable media, and methods for providing imaging functionality using a portable electronic device, such as, for example, a smart phone or a tablet computer. In some embodiments, the portable electronic device is configured to generate and display an image of what appears to be an exploded view (e.g., 3-dimensional, upwardly projected image) of an object or its constituent parts. In some embodiments, movement of the portable electronic device results in the rendering of a different internal image of the target (e.g., different portion(s) of a human body). In some embodiments, the generated window of the underlying object (e.g., the portion of the human body) may provide an internal view of the object (e.g., a three-dimensional rendering of an organ or a portion of an organ).

[0007] In some embodiments according to one aspect of the present disclosure, a portable electronic device is provided that includes a processor configured to generate an image (e.g., ultrasound image) of an internal feature of a

target when the device is positioned at an external surface of the target, and a display configured to display the image.

[0008] In some embodiments according to another aspect of the present disclosure, a portable ultrasound device is provided that includes multiple ultrasound elements configured to receive ultrasound radiation reflected by or passing through a target when the ultrasound device is pointed at the target. The portable ultrasound device also includes a display configured to display an image of an internal feature of the target based at least in part on the ultrasound radiation received by the plurality of ultrasound elements.

[0009] In some embodiments according to another aspect of the present disclosure, a method is provided that includes pointing a portable electronic device at an external surface of a subject, and viewing, on a display of the portable electronic device, an image of an internal feature of the subject while pointing the portable electronic device at the external surface of the subject. In some embodiments, the portable electronic device includes a radiation sensor, and the method further includes receiving, with the radiation sensor, radiation reflected by or passing through the subject, and creating the image of the internal feature based at least in part on the radiation received by the radiation sensor.

[0010] In some embodiments according to yet another aspect of the present disclosure, a portable electronic device is provided that renders within a window on a display of the device an image (e.g., 3-dimensional image) of an inside of a human body when the device is directed at the body (e.g., within about one meter or less of the body). In some embodiments, the image changes to reflect additional body parts as the device is moved relative to the body.

[0011] In some embodiments according to another aspect of the present disclosure, a portable electronic device is provided that includes multiple imaging elements configured to receive radiation signals transmitted through or reflected by an imaging target and an imaging interface. The portable electronic device also includes one or more processors configured to receive one or more sensing signals from at least one of the plurality of imaging elements, and to render an image of the imaging target for display through the imaging interface based at least in part on the one or more sensing signals.

### BRIEF DESCRIPTION OF DRAWINGS

[0012] Aspects and embodiments of the present disclosure will be described with reference to the following figures. It should be appreciated that the figures are not necessarily drawn to scale. Items appearing in multiple figures are indicated by the same reference number in all the figures in which they appear.

[0013] FIG. 1A illustrates a portable electronic device including an imaging interface for generating and/or rendering an internal image of a human body or a portion of a human body according to some embodiments of the present disclosure.

[0014] FIG. 1B illustrates a three-dimensional internal image of a portion of a human body that is generated and/or rendered by a portable electronic device according to some embodiments of the present disclosure.

[0015] FIG. 2A illustrates a front view of portable electronic device including an imaging interface according to some embodiments of the present disclosure.

[0016] FIG. 2B illustrates a back view of portable electronic device including imaging elements according to some embodiments of the present disclosure.

[0017] FIG. 3 illustrates a transmissive imaging system and method according to some embodiments of the present disclosure.

[0018] FIG. 4 illustrates a reflective imaging system and method according to some embodiments of the present disclosure.

[0019] FIG. 5 illustrates a transmissive and/or reflective imaging system and method according to some embodiments of the present disclosure.

[0020] FIG. 6A illustrates a portable electronic device including an imaging interface for generating and/or rendering an internal image of a portion of a human body at a first position and at a second position according to some embodiments of the present disclosure.

[0021] FIG. 6B illustrates a three-dimensional internal image of a portion of a human body at the first position shown in FIG. 6A that is generated and/or rendered by a portable electronic device according to some embodiments of the present disclosure.

[0022] FIG. 6C illustrates a three-dimensional internal image of a portion of a human body at the second position shown in FIG. 6A that is generated and/or rendered by a portable electronic device according to some embodiments of the present disclosure.

[0023] FIG. 7A illustrates a front view of a portable electronic device according to some embodiments of the present disclosure.

[0024] FIG. 7B illustrates a back view of a portable electronic device according to some embodiments of the present disclosure.

[0025] FIG. 7C illustrates a front view of a case for a portable electronic device according to some embodiments of the present disclosure.

[0026] FIG. 7D illustrates a back view of a case including imaging elements for a portable electronic device according to some embodiments of the present disclosure.

[0027] FIG. 8A illustrates a front view of a case for a portable electronic device according to some embodiments of the present disclosure.

[0028] FIG. 8B illustrates a back view of a case including a retaining mechanism for a modular unit utilized with a portable electronic device according to some embodiments of the present disclosure.

[0029] FIG. 8C illustrates a front view of a case for a portable electronic device according to some embodiments of the present disclosure.

[0030] FIG. 8D illustrates a back view of a case including a retaining mechanism for a modular unit utilized with a portable electronic device according to some embodiments of the present disclosure.

[0031] FIG. 8E illustrates a modular unit including an imaging circuit according to some embodiments of the present disclosure.

#### DETAILED DESCRIPTION

[0032] According to some embodiments of the present disclosure, a portable electronic device is provided that includes an imaging interface and one or more imaging elements. For example, the portable electronic device may be a cellular phone, personal digital assistant, smart phone, tablet device, digital camera, laptop computer, or the like.

An image may be generated and/or rendered utilizing the portable electronic device. For example, the portable electronic device may be utilized to simulate a “window” into an imaging target, such as a human body or portion of the body. The simulated “window” may provide a view of the inside of a human body or portion of the body, including organs, arteries, veins, tissues, bone, and/or other bodily contents or parts. For example, an image (e.g., ultrasound or sonographic image) may be generated that illustrates and/or simulates internal features of the imaging target for a user. In some embodiments, a real-time continuous or substantially real-time continuous image may be generated and/or rendered such that movement of the portable electronic device results in a substantially real-time updated image of the area that corresponds to the new position of the portable electronic device. In some embodiments, internal movement of the target object (e.g., such as expansion and/or contraction of organs) may be rendered in real-time by the portable electronic device.

[0033] In some embodiments, the portable electronic devices and methods described herein may include, be coupled to (e.g., via a suitable communications connection or port such as a USB link), or otherwise utilize one or more radiation sources, sensors, and/or transducers (e.g., array(s) of ultrasound transducers), front-end processing circuitry and associated processing techniques, and/or image reconstruction devices and/or methods, in order to generate and/or render images to a user according to the non-limiting embodiments described in detail throughout the present disclosure.

[0034] In some embodiments of the present disclosure, one or more of the devices described in FIGS. 1A-8E herein may include or be coupled to one or more ultrasound imaging elements (e.g., one or more arrays of ultrasound sources, sensors, and/or transducers). One or more computers or processors within the portable electronic device may perform image analysis and/or image rendering based at least in part on radiation signals received by an imaging device.

[0035] FIG. 1A illustrates a portable electronic device 100 including an imaging interface 102 for generating and/or rendering an internal image of a human body or a portion of a human body 106 according to some embodiments. FIG. 1B illustrates a three-dimensional internal image 110 of a portion of a human body that is generated and/or rendered by a portable electronic device 100 according to some embodiments. As shown in FIG. 1A, the portable electronic device 100 may be positioned in an area near (e.g. in contact with the surface of or within about one meter from the surface of) a portion of a human body that is to be imaged and/or analyzed. The portable electronic device 100 may include imaging elements 104 that are configured to transmit and/or receive radiation signals. The imaging elements 104, along with other components and functions of the portable electronic device 100 according to some embodiments of the present disclosure will be described in greater detail below with reference to FIG. 2A-2B. An internal image 110 as shown in FIG. 1B may be generated by the portable electronic device 100. The internal image 110 may be a three-dimensional internal image of a portion of the human body that appears to a viewer 117 to project upward from a surface of the portable electronic device 100, giving the viewer the perception of a viewing window into the underlying body. Through generation of the internal image, the portable

electronic device **100** may provide a window into the internal areas of the human body that are below the surface. As will be described in greater detail below with reference to FIGS. 6A-6C, the generated images may be real-time continuous images such that the images are dynamically updated based on movement of the portable electronic device **100** and/or the image target (e.g., internal organs of the human body).

**[0036]** FIG. 2A illustrates a front view of portable electronic device **100** including an imaging interface **102** according to some embodiments of the present disclosure. The imaging interface **102** of the portable electronic device **100** may include a display that is configured to output a two-dimensional (2-D) or three-dimensional (3-D) image of an imaging target. In some embodiments, the imaging interface **102** is interactive and is capable of receiving user input, for example through a touch-screen. An image that is displayed via the imaging interface **102** may be adjusted based on the received inputs, for example, to adjust zoom level, centering position, level of detail, depth of an underlying object to be imaged, resolution, brightness, color and/or the like of the image. For example, in some embodiments, imaging interface **102** may be configured to allow a user to selectively traverse various layers and imaging depths of the underlying object using, for example, the touch screen.

**[0037]** Portable electronic device **100** may render a three-dimensional image of the imaging target using any suitable method or combination of methods (e.g., anaglyph, polarization, eclipse, interference filtering, and/or autostereoscopy). For example, in some embodiments, the imaging interface **102** includes a circular polarizer and/or a linear polarizer such that a viewer having polarizing filtering spectacles can view a three-dimensional image. In some embodiments, the imaging interface **102** is configured to display alternating left and right images such that a viewer having spectacles with shutters that alternate in conjunction with the displayed image. In some embodiments, the imaging interface **102** may utilize an autostereoscopy method such that 3-D spectacles are not necessary for use by a viewer to view the three-dimensional image.

**[0038]** In some embodiments, portable electronic device **100** may display information (e.g., text and/or graphics) in addition to (e.g., graphically overlaid on top of or adjacent to) an image of a targeted object, such as, for example, text and/or graphics identifying the structure(s) identified in the image (e.g., organs, arteries, veins, tissues, bone, and/or other bodily contents or parts). In some embodiments, portable electronic device **100** may include one or more processors for identifying structure(s) identified in the image based at least in part on stored data (e.g., data stored in random access memory or other storage device of portable electronic device **100**). For example, data stored within device **100** may identify characteristic(s) of structure(s) (e.g., one or more shapes, colors, textures, cellular characteristics, tissue characteristics, and/or other distinctive and/or surrounding features or structures) that may be present within different areas of the human body for use by personal electronic device **100** to identify and/or predict the type(s) of structures depicted in an image rendered by device **100**. In some embodiments, data stored within device **100** may identify characteristics of particular disease(s) such as cancer or other abnormalities for use by personal electronic device **100** to identify and/or predict the type(s) of structures

depicted in an image rendered by device **100**. In some embodiments, the image, text, graphics, and/or other information displayed on the user interface **104** may be adjusted through user interaction with one or more inputs (e.g., touch screen, buttons, touch-sensitive areas, or the like) of the portable electronic device **100**.

**[0039]** FIG. 2B illustrates a back view of portable electronic device **100** including imaging elements **104** according to some embodiments of the present disclosure. The imaging elements **104** may be configured as sources (emitters) and/or sensors of ultrasound radiation and/or other radiation. In some embodiments, the imaging elements **104** may be of substantially the same size and/or may be arranged in an array as shown in FIG. 2B. In some embodiments, the imaging elements **104** may be of different sizes and/or arranged in an irregular or scattered configuration. In some embodiments, one or more (e.g., all) of the imaging elements **104** may be arranged in the same plane. In other embodiments, at least some of imaging elements may be arranged in at least two different planes. In some embodiments, all of the imaging elements **104** included in the portable electronic device **100** may be either emitting elements or sensing elements. In some embodiments, the imaging elements **104** may include both emitting elements and sensing elements. The embodiment shown in FIG. 2B includes a 4×6 array of imaging elements **104**, by way of illustration only and is not intended to be limiting. In other embodiments, any other suitable numbers of imaging elements may be provided (e.g., 10, 20, 30, 40, 50, 100, 200, 500, 1000, or any number in between, or more) and may be arranged in any suitable configuration.

**[0040]** In some embodiments, the imaging elements **104** may be integrated within a circuit board (e.g., a printed circuit board) that includes, for example, processing (e.g., image processing) components of the portable electronic device **100**. In some embodiments, the imaging elements **104** may be provided on a separate circuit board or layer of a circuit board than the processing components of the portable electronic device **100**, and may be in communication with the processing circuitry through a suitable communications link (e.g., an internal bus, USB link, or other port).

**[0041]** The imaging elements **104** according to some embodiments of the present disclosure may include their own dedicated processing circuitry, such as a graphic processing unit (GPU), digital signal processor (DSP), and/or central processing unit (CPU), and/or may utilize processing circuitry of the portable electronic device **100**. For example, in some embodiments, the CPU and/or GPU of the portable electronic device **100** may be utilized for image acquisition/reconstruction and image rendering. In some embodiments, the CPU of portable electronic device **100** may be utilized to process computations based on received signals (e.g., back-scattered signals and/or transmissive signals) in order to generate an image or topography, while the GPU may be utilized to render an image based on the information received from the CPU to generate a real-time or substantially real-time image display. In some embodiments, portable electronic device **100** may include one or more components for processing, filtering, amplification, and/or rendering images.

**[0042]** FIG. 3 illustrates a transmissive imaging system and method **301** according to some embodiments of the present disclosure. As shown in FIG. 3, the transmissive

imaging system **301** includes two portable electronic devices **100A** and **100B** that are on opposing or generally opposing sides of an imaging target **306**. In other embodiments, devices **100A** and **100B** may be positioned in any other relationship with respect to one another. In some embodiments, devices **100A** and/or **100B** may include one or more sensors for determining the relative positions of these devices to aid in the generation of image(s). While shown as a portable electronic device **100B** (e.g., smart phone), in some embodiments device **100B** may be a dedicated sensing and/or emitting device such as an array of ultrasound elements and associated circuitry. Signals (e.g., waves or beams **308**) emitted from the portable electronic device **100B** are sensed by the portable electronic device **100A** and are utilized to render a 2-D or 3-D image **312** (e.g., real-time or substantially real-time image) of the target **306**. In some embodiments, a generated 3-D image may be in the form of a pop-out image or a depth image. In some embodiments, the portable electronic device **100A** may be configured to transmit signals (e.g., waves or beams) **308** though the target **306** to be received by the portable electronic device **100B**. In some embodiments, the portable electronic device **100B** may simultaneously or substantially simultaneously render an image (e.g., back view or alternate view or level of detail of an image rendered by device **100A**) based at least in part on processing sensed signals. In some embodiments, the portable electronic devices **100A** and/or **100B** may communicate the results of the sensed signals to the other in order to generate or improve a rendered image.

**[0043]** FIG. 4 illustrates a back-scatter or reflective imaging system and method **401** according to some embodiments of the present disclosure. As shown in FIG. 4, a portable electronic device **100** may utilize emission and/or sensing elements **104** in order to render an image **410** based at least in part on reflection (e.g., back-scatter effect) of the signals **408**. In some embodiments, portable electronic device **100** is the only device utilized in order to image the target (e.g., to produce an image appearing as a window into a human body). For example, the portable electronic device **100** may include both radiation sources and sensors (e.g., separate sources and sensors, and/or multiple transducers functioning as both sources and sensors), where all or substantially all of the radiation utilized by the sensors to reconstruct image(s) is backscatter radiation or radiation produced through a similar effect.

**[0044]** FIG. 5 illustrates a transmissive and/or reflective imaging system and method **501** according to some embodiments of the present disclosure. As shown in FIG. 5, a plurality of devices, such as portable electronic devices **500A**, **500B**, **500C**, and/or **500D** may be utilized in order to render one or more image(s) **510** of target **506** on portable electronic device **500B**. Each of the portable electronic devices **500A-500D** may be configured to emit signals (e.g., waves or beams) **508** as shown in FIG. 5. The image **510**, or alternate views of the image or imaged structure, may be rendered on the other portable electronic devices (e.g., **500A**, **500C**, and **500D**) through communication with one-another. In some embodiments, each of the devices (e.g., **500A**, **500C**, and/or **500D**) may be configured as emitting and/or sensing devices only. The image **510** that is rendered on portable device **500B** may be based at least in part on signals **508** that are emitted by one or more of the devices

**500A-500D**, and which are sensed through reflection (e.g., back-scatter) and/or transmission by one or more of the devices **500A-500D**.

**[0045]** In some embodiments, one or more portable electronic devices according to the present disclosure may generate and/or render an image based solely on signals received by one or more sensors (e.g., ultrasound transducers) of the device. In some embodiments, one or more portable electronic devices according to the present disclosure may generate and/or render an image based at least in part on information stored in memory (e.g., random access memory) of the portable device(s) identifying detail(s) regarding the structure(s), part(s), composition(s), and/or other characteristic(s) of object(s) to be imaged. For example, in some embodiments, when data received by one or more sensor(s) of the portable electronic devices indicates that the object being imaged is a particular body part or region, the portable electronic devices may use stored data in addition to the received data in order to generate an image of the object and/or its constituent part(s), and/or to provide addition detail or explanation regarding an object and/or its constituent parts.

**[0046]** In some embodiments of the present disclosure, the generated and/or rendered image may be a real-time or substantially real-time image that is dynamically updated based on movement of a portable electronic device **100** along a surface of an imaging target and/or motion of the imaging target. FIG. 6A illustrates a portable electronic device **100** including an imaging interface **102** for generating and/or rendering an internal image of a portion of a human body at a first position and at a second position according to some embodiments. FIG. 6B illustrates a three-dimensional internal image **610** of a portion of a human body at the first position shown in FIG. 6A that is generated and/or rendered by a portable electronic device **100** according to some embodiments. FIG. 6C illustrates a three-dimensional internal image **610** of a portion of a human body at the second position shown in FIG. 6A that is generated and/or rendered by a portable electronic device **100** according to some embodiments. As shown in FIG. 6B, a three-dimensional internal image **610** of a portion of the human body may be generated and displayed to a viewer **617**. The three-dimensional image **610** may appear to the viewer **617** as an image having variations in, for example, topography that correspond to the surfaces and/or other aspects or features of the internal portion of the body at the first position of the portable electronic device **100** as shown in FIG. 6A. The three-dimensional image **610** may be a real-time continuous image that is dynamically updated based on movement of the portable electronic device **100** and/or the internal portion of the body that is being analyzed. As shown in FIG. 6C, a different three-dimensional internal image **610** is displayed to the viewer **617** showing different underlying structures and/or aspects (e.g., organs, arteries, veins, tissues, bone, and/or other bodily contents or parts). The three-dimensional internal image **610** shown in FIG. 6C corresponds to the internal image of the body portion corresponding to the second position of the portable electronic device **100** as shown in FIG. 6A. As shown in FIG. 6C, the internal image **610** is illustrated as a different image showing different topographical and/or other aspects or features of the body portion than the internal image **610** shown in FIG. 6B. As discussed above, through selection of different aspect ratios and/or zoom settings, as well as

through positioning of the portable electronic device 600, different types of internal images of a target may be generated, such as a three-dimensional view of an entire organ or multiple organs.

[0047] In some embodiments, the imaging elements, including sensors and/or sources (e.g., transducers), may be provided on, in, or otherwise coupled to a case for a portable electronic device. FIG. 7A illustrates a front view of a portable electronic device 700 according to some embodiments of the present disclosure. The portable electronic device 700 includes an imaging interface 702. FIG. 7B illustrates a back view of the portable electronic device 700 according to some embodiments of the present disclosure. As shown in FIGS. 7A and 7B, unlike the portable electronic device 100, the portable electronic device 700 does not include imaging elements 104 as part of the main housing or enclosure of device 700.

[0048] FIG. 7C illustrates a front view of a case 711 for a portable electronic device according to some embodiments of the present disclosure. FIG. 7D illustrates a back view of the case 711 including imaging elements for a portable electronic device according to some embodiments of the present disclosure. The case 711 may be configured to at least partially enclose the portable electronic device 700. In some embodiments, case 711 may simultaneously provide imaging capabilities to portable electronic device 700 and serve as a protective case. The case may be made of any suitable material such as rubber, plastic, leather, and/or the like. As shown in FIG. 7D, an imaging circuit 712 (e.g., an integrated circuit) may be provided on (e.g., directly on), embedded in, and/or otherwise coupled to the back surface and/or other surface(s) of the case 711. Case 711 may be considered part of portable electronic device 700.

[0049] The imaging circuit 712 may include one or more imaging elements 104. As discussed above, the imaging elements 104 may include sources and/or sensors. The imaging circuit 712 may also include a communication device 714 configured to communicate with the portable electronic device 700 via a wired or wireless link. For example, the imaging circuit 712 may include a communication transmitter/receiver which utilizes an infrared signal, a Bluetooth communication signal, a near-field communication signal, and/or the like to communicate with the portable electronic device 700. In some embodiments, the communication device 714 may be in communication with the processing circuitry of a portable electronic device through a wired communications link (e.g., a USB port, or other data port), or combination of wired and wireless links. In some embodiments, the imaging circuit 712 may receive power through wired and/or wireless connection(s) to the portable electronic device. In some embodiments, the imaging circuit 712 may receive power from a separate power source (e.g., a battery) that is coupled to the imaging circuit 712. In some embodiments, when the portable electronic device 700 is coupled to or attached to the case 711, a software application and/or drivers are automatically loaded and/or executed by the portable electronic device 700 in order to render an image based on communication with the imaging circuit 712. The software application and/or drivers may be stored in a memory of the imaging circuit 712 and communicated to the portable electronic device 700 and/or may be retrieved by the portable electronic device through a network (e.g., the internet).

[0050] In some embodiments, the portable electronic device 700 receives raw data from the communication device 714 and processes the raw data using processing circuitry (e.g., image signal processor, digital signal processor, filters, and/or the like) included in the portable electronic device 700. In some embodiments, the imaging circuit 712 includes a local imaging processor 716 configured to process signals received by imaging elements 104. The communication device 714 may be configured to communicate data received from the imaging elements 104 (e.g., such as raw sensor data) and/or may communicate processed data that is received from the local imaging processor 716. As shown in FIG. 7A, the portable electronic device 700 includes an interface 702 for displaying an image that is rendered by processing signals received from the communication device 714.

[0051] In some embodiments, an imaging circuit (e.g., an integrated circuit) may be provided separately such that it can be mounted and/or attached to different cases used by different portable electronic devices. FIG. 8A illustrates a front view of a case 811A for a portable electronic device according to some embodiments of the present disclosure. FIG. 8B illustrates a back view of the case 811A including a retaining mechanism 820 for a modular unit 830 utilized with a portable electronic device according to some embodiments of the present disclosure. FIG. 8C illustrates a front view of a case 811B for a portable electronic device according to some embodiments of the present disclosure. FIG. 8D illustrates a back view of the case 811B including a retaining mechanism for a modular unit 830 utilized with a portable electronic device according to some embodiments of the present disclosure. FIG. 8E illustrates a modular unit 830 including an imaging circuit 712 according to some embodiments of the present disclosure. As shown in FIGS. 8A-8D, the case 811A has a different shape than the case 811B. The case 811A may be utilized for a first portable electronic device, while the case 811B may be utilized for a second portable electronic device having a different size and/or shape than the first portable electronic device. Each of the cases 811A and 811B includes a retaining mechanism 820 that is configured to retain the modular unit 830.

[0052] The modular unit 830 may include the imaging circuit 712 as discussed above with reference to FIGS. 7A-7D. The imaging circuit 712 may include one or more imaging elements 104, a communication device 714, and/or a local imaging processor 716. The modular unit 830 also includes a coupling mechanism 832 that is configured to engage with the retaining mechanism 820 of the cases 811A and 811B. For example, in some embodiments, the retaining mechanism 820 may correspond to a slot on the case 811A and/or 811B that is configured to receive the modular unit 830. The coupling mechanism 832 may be shaped to correspond to the slot of the case 811A and/or 811B such that the modular unit 830 may be secured by the case 811A and/or 811B. In some embodiments, the retaining mechanism 820 and the coupling mechanism 832 may include corresponding structures for locking the modular unit 830 in place during use. In some embodiments, the retaining mechanism 820 may include one or more magnets having a first polarity, and the coupling mechanism 832 may include one or more magnets having a second polarity that is opposite of the first polarity such that the modular unit 830 can be retained by the case 811A and/or 811B.

**[0053]** As described with reference to FIGS. 8A-8E, since the modular unit **830** may be incorporated with different cases **811A** and/or **811B** that are utilized for different portable electronic devices, the modular unit **830** may advantageously provide flexibility in the incorporation of an imaging system with different portable electronic devices. Furthermore, different cases **811A** and **811B** may be manufactured using any suitable techniques (e.g., 3-D printing, injection molding, or the like). In some embodiments, case **811A** and/or case **811B** may be manufactured at low cost such that the different cases **811A** and **811B** may be discarded and/or upgraded while remaining compatible with the modular unit **830**. As a result, the modular unit **830** can be integrated into and utilized by a user with a plurality of portable electronic devices even when the design of the portable electronic devices is changed (e.g., updated and/or upgraded).

**[0054]** Examples of suitable imaging devices that may be integrated within or coupled to a portable electronic device according to some embodiments of the present disclosure are described in commonly-owned U.S. patent application Ser. No. 13/654,337 filed Oct. 17, 2012, and entitled “Transmissive Imaging and Related Apparatus and Methods;” U.S. Provisional Application Ser. No. 61/798,851 filed Mar. 15, 2013, and entitled “Monolithic Ultrasonic Imaging Devices, Systems and Methods;” and U.S. Provisional Application Ser. No. 61/794,744 filed on Mar. 15, 2013, and entitled “Complementary Metal Oxide Semiconductor (CMOS) Ultrasonic Transducers and Methods for Forming the Same,” each of which is incorporated by reference in its entirety.

**[0055]** Having thus described several aspects and embodiments of the technology described herein, it is to be appreciated that various alterations, modifications, and improvements will readily occur to those skilled in the art. Such alterations, modifications, and improvements are intended to be within the spirit and scope of the technology described in the present disclosure. For example, those of ordinary skill in the art will readily envision a variety of other means and/or structures for performing the function and/or obtaining the results and/or one or more of the advantages described herein, and each of such variations and/or modifications is deemed to be within the scope of the embodiments described herein. Those skilled in the art will recognize, or be able to ascertain using no more than routine experimentation, many equivalents to the specific embodiments described herein. It is, therefore, to be understood that the foregoing embodiments are presented by way of example only and that, within the scope of the appended claims and equivalents thereto, inventive embodiments may be practiced otherwise than as specifically described. In addition, any combination of two or more features, systems, articles, materials, kits, and/or methods described herein, if such features, systems, articles, materials, kits, and/or methods are not mutually inconsistent, is included within the scope of the present disclosure.

**[0056]** The above-described embodiments can be implemented in any of numerous ways. One or more aspects and embodiments of the present disclosure involving the performance of processes or methods may utilize program instructions executable by a device (e.g., a computer, a processor, or other device) to perform, or control performance of, the processes or methods. In this respect, various inventive concepts may be embodied as a computer readable storage

medium (or multiple computer readable storage media) (e.g., a non-transitory computer memory, one or more floppy discs, compact discs, optical discs, magnetic tapes, flash memories, circuit configurations in Field Programmable Gate Arrays or other semiconductor devices, or other tangible computer storage medium) encoded with one or more programs that, when executed on one or more computers or other processors, perform methods that implement one or more of the various embodiments described above. The computer readable medium or media can be transportable, such that the program or programs stored thereon can be loaded onto one or more different computers or other processors to implement various ones of the aspects described above. In some embodiments, computer readable media may be non-transitory media.

**[0057]** The terms “program” or “software” are used herein in a generic sense to refer to any type of computer code or set of computer-executable instructions that can be employed to program a computer or other processor to implement various aspects as described above. Additionally, it should be appreciated that according to one aspect, one or more computer programs that when executed perform methods of the present application need not reside on a single computer or processor, but may be distributed in a modular fashion among a number of different computers or processors to implement various aspects of the present application.

**[0058]** Computer-executable instructions may be in many forms, such as program modules, executed by one or more computers or other devices. Generally, program modules include routines, programs, objects, components, data structures, etc. that perform particular tasks or implement particular abstract data types. Typically the functionality of the program modules may be combined or distributed as desired in various embodiments.

**[0059]** Also, data structures may be stored in computer-readable media in any suitable form. For simplicity of illustration, data structures may be shown to have fields that are related through location in the data structure. Such relationships may likewise be achieved by assigning storage for the fields with locations in a computer-readable medium that convey relationship between the fields. However, any suitable mechanism may be used to establish a relationship between information in fields of a data structure, including through the use of pointers, tags or other mechanisms that establish relationship between data elements.

**[0060]** When implemented in software, the software code can be executed on any suitable processor or collection of processors, whether provided in a single computer or distributed among multiple computers.

**[0061]** Further, it should be appreciated that a computer may be embodied in any of a number of forms, such as a rack-mounted computer, a desktop computer, a laptop computer, or a tablet computer, as non-limiting examples. Additionally, a computer may be embedded in a device not generally regarded as a computer but with suitable processing capabilities, including a Personal Digital Assistant (PDA), a smart phone or any other suitable portable or fixed electronic device.

**[0062]** Also, a computer may have one or more input and output devices. These devices can be used, among other things, to present a user interface. Examples of output devices that can be used to provide a user interface include printers or display screens for visual presentation of output and speakers or other sound generating devices for audible

presentation of output. Examples of input devices that can be used for a user interface include keyboards, and pointing devices, such as mice, touch pads, and digitizing tablets. As another example, a computer may receive input information through speech recognition or in other audible formats.

**[0063]** Such computers may be interconnected by one or more networks in any suitable form, including a local area network or a wide area network, such as an enterprise network, and intelligent network (IN) or the Internet. Such networks may be based on any suitable technology and may operate according to any suitable protocol and may include wireless networks, wired networks or fiber optic networks.

**[0064]** Also, as described, some aspects may be embodied as one or more methods. The acts performed as part of the method may be ordered in any suitable way. Accordingly, embodiments may be constructed in which acts are performed in an order different than illustrated, which may include performing some acts simultaneously, even though shown as sequential acts in illustrative embodiments.

**[0065]** All definitions, as defined and used herein, should be understood to control over dictionary definitions and/or ordinary meanings of the defined terms.

**[0066]** The indefinite articles “a” and “an,” as used herein in the specification and in the claims, unless clearly indicated to the contrary, should be understood to mean “at least one.”

**[0067]** The phrase “and/or,” as used herein in the specification and in the claims, should be understood to mean “either or both” of the elements so conjoined, i.e., elements that are conjunctively present in some cases and disjunctively present in other cases. Multiple elements listed with “and/or” should be construed in the same fashion, i.e., “one or more” of the elements so conjoined. Other elements may optionally be present other than the elements specifically identified by the “and/or” clause, whether related or unrelated to those elements specifically identified. Thus, as a non-limiting example, a reference to “A and/or B”, when used in conjunction with open-ended language such as “comprising” can refer, in one embodiment, to A only (optionally including elements other than B); in another embodiment, to B only (optionally including elements other than A); in yet another embodiment, to both A and B (optionally including other elements); etc.

**[0068]** As used herein in the specification and in the claims, the phrase “at least one,” in reference to a list of one or more elements, should be understood to mean at least one element selected from any one or more of the elements in the list of elements, but not necessarily including at least one of each and every element specifically listed within the list of elements and not excluding any combinations of elements in the list of elements. This definition also allows that elements may optionally be present other than the elements specifically identified within the list of elements to which the phrase “at least one” refers, whether related or unrelated to those elements specifically identified. Thus, as a non-limiting example, “at least one of A and B” (or, equivalently, “at least one of A or B,” or, equivalently “at least one of A and/or B”) can refer, in one embodiment, to at least one, optionally including more than one, A, with no B present (and optionally including elements other than B); in another embodiment, to at least one, optionally including more than one, B, with no A present (and optionally including elements other than A); in yet another embodiment, to at least one, option-

ally including more than one, A, and at least one, optionally including more than one, B (and optionally including other elements); etc.

**[0069]** Also, the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. The use of “including,” “comprising,” or “having,” “containing,” “involving,” and variations thereof herein, is meant to encompass the items listed thereafter and equivalents thereof as well as additional items.

**1-66.** (canceled)

**67.** A computer-implemented method, comprising:

generating, using a portable imaging device, at least one multi-dimensional image of at least a portion of an object while the portable imaging device is directed at the object;

enhancing the at least one generated multi-dimensional image using a first data provided by the portable imaging device;

rendering, by the portable imaging device, at least one enhanced multi-dimensional image; and

updating the at least one enhanced multi-dimensional image based on an updated position of the portable imaging device in relation to the object.

**68.** The method according to claim **67**, wherein the generating includes

receiving, by at least one sensor of the portable imaging device, at least one image signal, wherein the at least one image signal is received by the at least one sensor using at least one of the following: a reflection from the object, a transmission through the object, and any combination thereof; and

generating, based on the at least one received image signal, a virtual window for displaying the at least one multi-dimensional image.

**69.** The method according to claim **68**, wherein the rendering includes

displaying, using the portable imaging device, the at least one enhanced multi-dimensional image within the generated virtual window.

**70.** The method according to claim **67**, wherein the first data includes at least one of the following: a graphic, a topography, a text, and any combination thereof.

**71.** The method according to claim **67**, wherein the first data includes an identification of at least one characteristic of the portion of the object.

**72.** The method according to claim **71**, wherein the at least one characteristic includes at least one of the following: a shape, a color, a texture, a cellular characteristic, a tissue characteristic, and any combination thereof of at least one of the following: the portion of the object, another portion of the object, and any combination thereof.

**73.** The method according to claim **67**, wherein the enhancing includes at least one of the following:

adjusting at least one of the following: a zoom level, a centering position, a level of detail, a depth, a resolution, a brightness, a color, and any combination thereof of the at least one generated multi-dimensional image; traversing at least one layer of the at least one generated multi-dimensional image;

traversing at least one imaging depth of the at least one generated multi-dimensional image; and any combination thereof.

**74.** The method according to claim **67**, wherein the at least one multi-dimensional image includes at least one of the

following: a real-time image, a continuous image, a two-dimensional image, a three-dimensional image, a polarized image, an exploded image, and any combination thereof.

**75.** The method according to claim **67**, wherein the object includes at least one of the following: a human body and a portion of a human body.

**76.** The method according to claim **67**, wherein the portable imaging device is positioned remotely from the object.

**77.** The method according to claim **67**, wherein at portable imaging device includes at least one of the following: a cellular telephone; a personal digital assistant; a smartphone; a tablet device; a digital camera; a laptop computer; an ultrasound device; an ultrasound transducer; an array of ultrasound transducers; an ultrasound imaging element; a device including at least one of the following: at least one ultrasound transducer, at least one array of ultrasound transducers, at least one ultrasound source, at least one an ultrasound imaging element, at least one ultrasound sensor, at least one radiation element, and any combination thereof; and any combination thereof.

**78.** The method according to claim **67**, wherein the first data is stored by the portable imaging device.

**79.** A system comprising:

at least one programmable processor; and

a machine-readable medium storing instructions that, when executed by the at least one programmable processor, cause the at least one programmable processor to perform operations comprising:

generating, using a portable imaging device, at least one multi-dimensional image of at least a portion of an object while the portable imaging device is directed at the object;

enhancing the at least one generated multi-dimensional image using a first data provided by the portable imaging device;

rendering, by the portable imaging device, at least one enhanced multi-dimensional image; and

updating the at least one enhanced multi-dimensional image based on an updated position of the portable imaging device in relation to the object.

**80.** The system according to claim **79**, wherein the generating includes

receiving, by at least one sensor of the portable imaging device, at least one image signal, wherein the at least one image signal is received by the at least one sensor using at least one of the following: a reflection from the object, a transmission through the object, and any combination thereof; and

generating, based on the at least one received image signal, a virtual window for displaying the at least one multi-dimensional image.

**81.** The system according to claim **80**, wherein the rendering includes

displaying, using the portable imaging device, the at least one enhanced multi-dimensional image within the generated virtual window.

**82.** The system according to claim **79**, wherein the first data includes at least one of the following: a graphic, a topography, a text, and any combination thereof.

**83.** The system according to claim **79**, wherein the first data includes an identification of at least one characteristic of the portion of the object.

**84.** The system according to claim **83**, wherein the at least one characteristic includes at least one of the following: a shape, a color, a texture, a cellular characteristic, a tissue characteristic, and any combination thereof of at least one of the following: the portion of the object, another portion of the object, and any combination thereof.

**85.** The system according to claim **79**, wherein the enhancing includes at least one of the following:

adjusting at least one of the following: a zoom level, a centering position, a level of detail, a depth, a resolution, a brightness, a color, and any combination thereof of the at least one generated multi-dimensional image;

traversing at least one layer of the at least one generated multi-dimensional image;

traversing at least one imaging depth of the at least one generated multi-dimensional image; and

any combination thereof.

**86.** The system according to claim **79**, wherein the at least one multi-dimensional image includes at least one of the following: a real-time image, a continuous image, a two-dimensional image, a three-dimensional image, a polarized image, an exploded image, and any combination thereof.

**87.** The system according to claim **79**, wherein the object includes at least one of the following: a human body and a portion of a human body.

**88.** The system according to claim **79**, wherein the portable imaging device is positioned remotely from the object.

**89.** The system according to claim **79**, wherein at portable imaging device includes at least one of the following: a cellular telephone; a personal digital assistant; a smartphone; a tablet device; a digital camera; a laptop computer; an ultrasound device; an ultrasound transducer; an array of ultrasound transducers; an ultrasound imaging element; a device including at least one of the following: at least one ultrasound transducer, at least one array of ultrasound transducers, at least one ultrasound source, at least one an ultrasound imaging element, at least one ultrasound sensor, at least one radiation element, and any combination thereof; and any combination thereof.

**90.** The system according to claim **79**, wherein the first data is stored by the portable imaging device.

**91.** A computer program product comprising a non-transitory machine-readable medium storing instructions that, when executed by at least one programmable processor, cause the at least one programmable processor to perform operations comprising:

generating, using a portable imaging device, at least one multi-dimensional image of at least a portion of an object while the portable imaging device is directed at the object;

enhancing the at least one generated multi-dimensional image using a first data provided by the portable imaging device;

rendering, by the portable imaging device, at least one enhanced multi-dimensional image; and

updating the at least one enhanced multi-dimensional image based on an updated position of the portable imaging device in relation to the object.

**92.** The computer program product according to claim **91**, wherein the generating includes

receiving, by at least one sensor of the portable imaging device, at least one image signal, wherein the at least one image signal is received by the at least one sensor

using at least one of the following: a reflection from the object, a transmission through the object, and any combination thereof; and

generating, based on the at least one received image signal, a virtual window for displaying the at least one multi-dimensional image.

**93.** The computer program product according to claim **92**, wherein the rendering includes

displaying, using the portable imaging device, the at least one enhanced multi-dimensional image within the generated virtual window.

**94.** The computer program product according to claim **91**, wherein the first data includes at least one of the following: a graphic, a topography, a text, and any combination thereof.

**95.** The computer program product according to claim **91**, wherein the first data includes an identification of at least one characteristic of the portion of the object.

**96.** The computer program product according to claim **95**, wherein the at least one characteristic includes at least one of the following: a shape, a color, a texture, a cellular characteristic, a tissue characteristic, and any combination thereof of at least one of the following: the portion of the object, another portion of the object, and any combination thereof.

**97.** The computer program product according to claim **91**, wherein the enhancing includes at least one of the following:

adjusting at least one of the following: a zoom level, a centering position, a level of detail, a depth, a resolution, a brightness, a color, and any combination thereof of the at least one generated multi-dimensional image; traversing at least one layer of the at least one generated multi-dimensional image;

traversing at least one imaging depth of the at least one generated multi-dimensional image; and

any combination thereof.

**98.** The computer program product according to claim **91**, wherein the at least one multi-dimensional image includes at least one of the following: a real-time image, a continuous image, a two-dimensional image, a three-dimensional image, a polarized image, an exploded image, and any combination thereof.

**99.** The computer program product according to claim **91**, wherein the object includes at least one of the following: a human body and a portion of a human body.

**100.** The computer program product according to claim **91**, wherein the portable imaging device is positioned remotely from the object.

**101.** The computer program product according to claim **91**, wherein at portable imaging device includes at least one of the following: a cellular telephone; a personal digital assistant; a smartphone; a tablet device; a digital camera; a laptop computer; an ultrasound device; an ultrasound transducer; an array of ultrasound transducers; an ultrasound imaging element; a device including at least one of the following: at least one ultrasound transducer, at least one array of ultrasound transducers, at least one ultrasound source, at least one an ultrasound imaging element, at least one ultrasound sensor, at least one radiation element, and any combination thereof; and any combination thereof.

**102.** The computer program product according to claim **91**, wherein the first data is stored by the portable imaging device.

\* \* \* \* \*